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# A 17th Century Destructive Seismic Crisis in the Gargano Area: Its Implications on the Understanding of Local Seismicity

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*A significant and partly forgotten series of earthquakes located in the Gargano area (Southern Italy) between 1646 and 1688 AD is critically revised, in the light of newly discovered historical records derived from non local contemporary serial sources (early newspapers and diplomatic reports). The revision is conducted in the frame of a survey of the current state of knowledge on historical Gargano seismicity. Hypotheses on the seismotectonic effects of the evente and their influences on the evaluation of local seismic hazard are also proposed.*

**Keywords** Historical Seismology; Earthquake Catalogs Completeness; Local Seismicity; Unknown Earthquakes

## 1. Introduction

This study is a spin-off from a wider ongoing investigation of 16th–18th centuries European newspapers and diplomatic sources. Early modern journalists and diplomats routinely collected information on what was going on (in Europe and abroad) and disseminated it via newspapers and confidential reports. As their interest did not stop at man-engineered events, but extended to natural ones, their writings are a potential mine of knowledge on historical earthquakes. The ongoing systematic perusal of early journalistic and diplomatic sources has had encouraging results, useful for improving knowledge on otherwise poorly known earthquakes and also for rediscovering ''forgotten'' earthquakes, i.e., ones whose occurrence has so far failed to recorded by the current catalogs [Camassi and Castelli, 2004, 2005; Castelli and Camassi, 2005].

Among the journalistic and diplomatic evidence thus collected, there are several records of 17th–19th century earthquakes (Table 1) in the Gargano peninsula (SE Italy), a seismically active offshoot of the Apennines, best visualized as ''the spur on Italy's boot.'' This article focuses on the records collected on 17th century Gargano earthquakes, whose critical examination allows to draw a better picture of the strong but comparatively poorly known earthquake of 1646, and also to reconstruct in some detail the seismic context in which it occurred. In the following chapters, new studies are provided for the 1646 earthquake, and for a ''forgotten'' earthquake (1647) and two ''underestimated''

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**TABLE 1** Informations available on poorly known or unknown earthquakes of the Gargano area after this study (HD: Heavy Damage; SD: Slight Damage; D: Damage; HF: Heavily Felt; SF: Slightly Felt). POS85 = [Postpischl, 1985]; CPTI04 = [CPTI Working Group, 2004]

| Date | Locality/Area | Lat | Lon | Is | Remarks/sources |
|---|---|---|---|---|---|
| 1223 | Siponto | 41.609 | 15.890 | HD | Known to POS85 and CPTI04. Doubtful event |
| | Vico del Gargano | 41.895 | 15.958 | HD | |
| | Sfilzi | 41.852 | 16.004 | HD | |
| | Vieste | 41.882 | 16.179 | 7/8 | |
| 1294 | Capitanata | 0.000 | 0.000 | HD | Unknown |
| 1414 | Vieste | 41.882 | 16.179 | HD | Known to POS85 and CPTI04. Doubtful event |
| 1656 10 17 | Gargano | 0.000 | 0.000 | HF | Known to POS85 |
| 1718 03 | Foggia | 41.460 | 15.553 | 5 | Unknown [Bologna, 1718a] |
| 1718 09 | Torremaggiore | 41.689 | 15.292 | 5 | Unknown [Bologna, 1718b] |
| 1739 02 13 | Foggia | 41.460 | 15.553 | 5/6 | Known to POS85 and CPTI04 |
| | Puglia | 0.000 | 0.000 | | |
| | Principato Citra | 0.000 | 0.000 | | |
| | Principato Ultra | 0.000 | 0.000 | | |
| | Napoli | 40.855 | 14.260 | SF | |
| 1756 11 22 | Manfredonia | 41.623 | 15.908 | 6/7 | Unknown [Bologna, 1756] |
| 1783 11 15 | Torremaggiore | 41.689 | 15.292 | D | Known to POS85 and CPTI04 |
| 1828 11 11 | San Severo | 41.685 | 15.381 | 5 | Unknown [Giornale del Regno delle Due Sicilie, 1828] |
| | Serracapriola | 41.806 | 15.159 | 5 | |
| 1829 07 03 | Lesina | 41.864 | 15.353 | 6 | Unknown [Giornale del Regno delle Due Sicilie, 1829] |
| | San Severo | 41.685 | 15.381 | 5 | |
| 1850 01 29 | Monte Sant' Angelo | 41.706 | 15.959 | 5 | Unknown [Perrey, 1851] |
| 1850 02 27 | Monte Sant' Angelo | 41.706 | 15.959 | 5 | Unknown [Perrey, 1851] |
| 1864 12 28 | Sannicandro | 41.835 | 15.567 | 7 | Known to POS85 and CPTI04 |

(*Continued*)

**TABLE 1** (*Continued*)

| Date | Locality/Area | Lat | Lon | Is | Remarks/sources |
|---|---|---|---|---|---|
| | Lesina | 41.864 | 15.353 | 3 | |
| | Vieste | 41.882 | 16.179 | 3 | |
| 1866 10 13 | Foggia | 41.460 | 15.553 | 5 | Unknown [Perrey, 1870] |
| 1869 03 31 | S. Giovanni Rotondo | 41.706 | 15.728 | 6/7 | Known to POS85 and CPTI04 |
| | S. Marco in Lamis | 41.712 | 15.636 | 5/6 | |
| | Sannicandro | 41.835 | 15.567 | F | |
| 1871 08 01 | Torre Mileto | 41.925 | 15.617 | 5 | Known to POS85 and CPTI04 |
| 1941 08 20 | San Severo | 41.700 | 15.400 | – | Known to POS85 and CPTI04 No macroseismic informations. |

ones (1656–1657, 1688). Finally, as the results of these studies lead to a global reassessment of Gargano seismicity in the 17$^{th}$ century time-window, their possible influence on the understanding of local seismotectonics and the evaluation of local seismic hazard will be discussed.

## 2. Geological Setting

The main structural element of Southern Italy is the Southern Apenninic arc, a complex of stacked nappes due to the progressive advance of the belt over the Apulian foreland [Patacca and Scandone, 2007]. In Fig. 1, the dashed black line with triangles represents the most advanced position of the allochthonous rocks of the thrust-related folds. The advancement of this front over the Apulian area stopped around 650,000 years ago [Meletti *et al*., 2000] and the whole area is characterized by an uplifting that increases from East to West.

The Gargano peninsula stretches out from the southern Adriatic coast of Italy with a roughly East-West trend. Although it lies out of the main Italian peninsula seismogenic belt, which runs along the axis of the Apenninic range, the Gargano peninsula shows an intense seismic activity. According to the current catalogs, considerable earthquakes affected this area, at fairly regular intervals, at least from the 1200's onward; but these data could be incomplete, many authors believe. The present understanding of the regional tectonics and their relationship with the kinematic framework of the Central Mediterranean sea is undoubtedly incomplete, as witnessed by the Mw 5.8 Molise earthquake of October 31, 2002 [CPTI Working Group, 2004], which occurred in an area where the available geological and historical information did not lead to expecting an earthquake of that magnitude.

From the seismotectonic point of view, the Gargano area is less satisfactorily known than the Southern Apennines, a region that was extensively investigated due to occurrence of some of the strongest earthquakes in Italy (e.g., the Mw 6.9 Irpinia earthquake of November 23, 1980 [CPTI Working Group, 2004]). The most relevant structural element in the entire Gargano area is the so-called Mattinata Fault, a dominant feature affecting

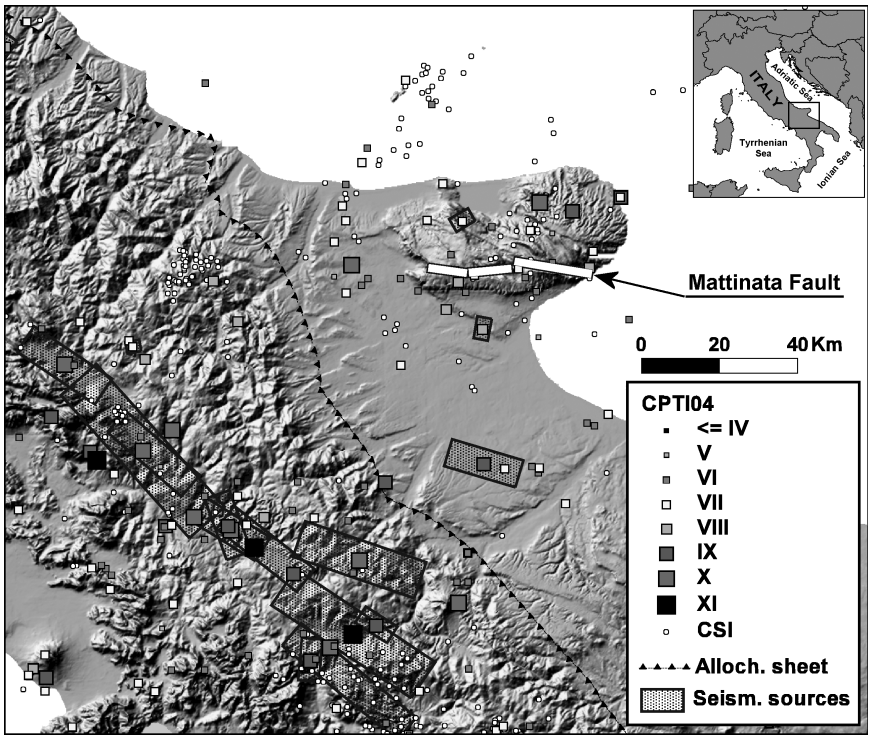


**FIGURE 1** The main elements to be considered in the seismotectonic analysis: historical seismicity, recent seismicity and main seismogenic known sources of the studied area. Shaded rectangles represent the seismogenic sources thought to have generated earthquakes above 5.5 according to the Database of Potential Sources for Earthquake larger that M 5.5 in Italy [DISS Working Group, 2005]; the Mattinata fault system is evidenced by white rectangles. Squares show the seismicity as reported in the CPTI04 catalogue [CPTI Working Group, 2004] Small dots represent earthquakes with a magnitude higher than 3 from the instrumental catalogue [CSI Working Group, 2005] from 1982 A.D. to 2002 A.D.

the morphological structure of the southern side of the peninsula (Fig. 1). This strong influence on the landscape enticed several past authors to analyze its geological and kinematic structures. However, no consensus on the kinematic behavior of the fault, or its present activity, has ever been reached, mainly on account of the difficulties in recognizing and dating kinematic indicators in the Mesozoic-Tertiary carbonates that constitute the Gargano promontory. A review of the different theories on this subject is given by Patacca and Scandone [2004], among others.

A new interpretation of the kinematic active processes in the Gargano region is presented in Meletti *et al*. [2008], in order to define the seismic source zones model to be used for seismic hazard assessment in Italy.

## 3. Historical and Recent Seismicity According to the Current Catalogue

The current Italian parametric earthquake catalog [CPTI Working Group, 2004] lists some 40 earthquakes (about half of which with magnitude $\geq$ 4.8) that occurred in the

Gargano peninsula from AD 1223 onward (Table 2). The amount of historical information available for each of them is variable in size and quality. Four of the strongest earthquakes on record (1223, 1414, 1627, 1646) occurred before 1650 AD (Fig. 2). Recent studies are available for them all [Boschi *et al*., 2000; Guidoboni and Comastri, 2005], but the historical evidence available on the 1223 and 1414 earthquakes remains scanty and unverifiable, consisting as it does of $17^{th}$–$18^{th}$ centuries accounts, allegedly based on contemporary sources that are not available anymore for critical analysis. Contemporary sources are available both for the 1627 and the 1646 earthquakes, but the former (with 65 macroseismic datapoints to its name) has a much better defined macroseismic field than the latter, for which only 18 macroseismic are available (Table 3). In the post-1650 time-window, only the earthquakes with a higher magnitude have been recently studied and can be deemed comparatively well known; this is not the case, however, for several lesser damaging earthquakes, the most recent studies of which are more than a century old [Baratta, 1901].

For what concerns instrumental seismicity, significant activity was recorded in the Gargano area during the last 20 years, with over 600 earthquakes covering short-lived and

**TABLE 2** Historical earthquakes of the Gargano area ($M \geq 4.8$) as listed in the current Italian earthquake parametric catalogue [CPTI Working Group, 2004]; CFTI = [Boschi *et al*., 2000]; POS85 = [Postpischl, 1985]; DOM = [Monachesi and Stucchi, 1997]

| Date | Epicentral Area | Epic. Int. | Macros. obs. | Lat. | Lon. | Ma | Rt |
|---|---|---|---|---|---|---|---|
| 1223 | Gargano | 9 | 5 | 41.85 | 16.03 | 6.0 | CFTI |
| 1414 | Vieste | 8/9 | 1 | 41.88 | 16.18 | 5.8 | CFTI |
| 1627 07 30 | Gargano | 10 | 65 | 41.73 | 15.35 | 6.7 | CFTI |
| 1646 05 31 | Gargano | 9/10 | 18 | 41.87 | 15.93 | 6.2 | CFTI |
| 1657 01 00 | Apricena | 7 | – | 41.83 | 15.33 | 4.8 | POS85 |
| 1739 02 13 | Foggia | 7 | – | 41.5 | 15.5 | 4.8 | POS85 |
| 1783 11 15 | San Severo | 7 | – | 41.67 | 15.33 | 4.8 | POS85 |
| 1841 02 21 | San Marco in Lamis | 7/8 | 13 | 41.63 | 15.64 | 5.1 | DOM |
| 1864 12 28 | Coppa Ferrata | 7 | – | 41.83 | 15.58 | 4.8 | POS85 |
| 1869 03 31 | San Giovanni | 7 | – | 41.72 | 15.75 | 4.8 | POS85 |
| 1871 08 01 | Torre Mileto | 7 | – | 41.92 | 15.63 | 4.8 | POS85 |
| 1875 12 06 | San Marco in Lamis | 7/8 | 97 | 41.69 | 15.68 | 6.1 | DOM |
| 1889 12 08 | Apricena | 7 | 122 | 41.83 | 15.69 | 5.4 | DOM |
| 1892 04 20 | Gargano | 6/7 | 15 | 41.76 | 16.09 | 4.8 | DOM |
| 1893 08 10 | Gargano | 8 | 69 | 41.72 | 16.08 | 5.2 | CFTI |
| 1894 03 25 | Lesina | 7 | 29 | 41.87 | 15.32 | 4.8 | DOM |
| 1941 08 20 | San Severo | – | – | 41.7 | 15.4 | 5.1 | POS85 |
| 1948 08 18 | Puglia Settentrionale | 7/8 | 59 | 41.58 | 15.75 | 5.4 | CFTI |
| 1951 01 16 | Gargano | 7 | 73 | 41.81 | 15.9 | 5.0 | DOM |
| 1955 02 09 | Monte Sant' Angelo | 7 | 31 | 41.72 | 15.86 | 4.8 | DOM |

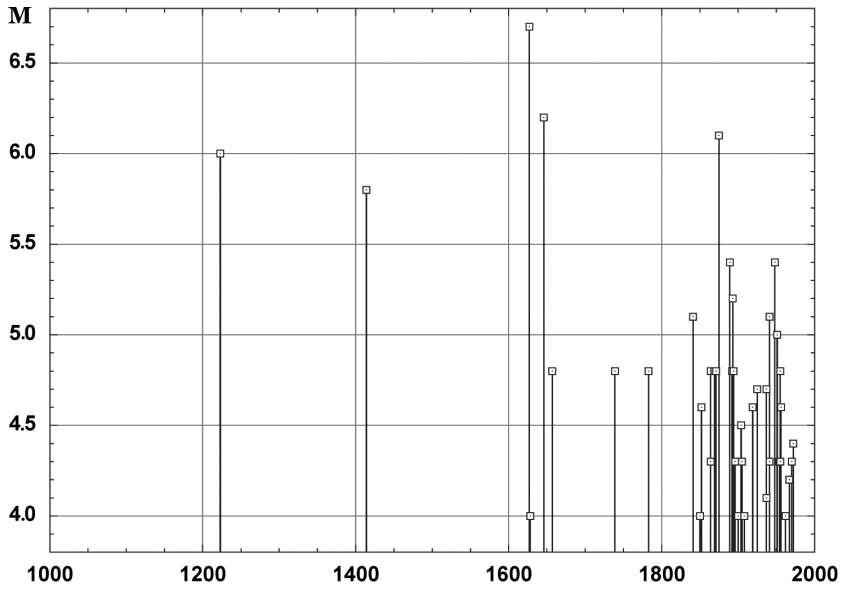


**FIGURE 2** Sesmicity time distribution of the Gargano area [CPTI Working Group, 2004].

**TABLE 3** Effects of the 1646 earthquake (MCS scale) according to Baratta [1901] and Boschi *et al*. [2000] (EE = environmental effects; F = Felt)

| Quoted locality | Lat. | Lon. | Baratta, 1901 | Boschi *et al*. [2000] |
|---|---|---|---|---|
| Cagnano Varano | 41.826 | 15.775 | 8 | 8/9 |
| Carpino | 41.843 | 15.857 | EE | 9/10 |
| Ischitella | 41.904 | 15.898 | 9/10 | 9/10 |
| Manfredonia | 41.623 | 15.908 | 8 | 8 |
| Monte Sant'Angelo | 41.706 | 15.959 | 8/9 | 9 |
| Peschici | 41.947 | 16.014 | 7/8 | 8 |
| Rodi Garganico | 41.929 | 15.884 | 8 | 8 |
| San Giovanni Rotondo | 41.706 | 15.728 | 7/8 | F |
| Vico del Gargano | 41.895 | 15.958 | 9 | 9 |
| Vieste | 41.882 | 16.179 | 9 | 9 |
| Bari | 41.106 | 16.846 | – | F |
| Cassano delle Murge | 40.889 | 16.771 | – | F |
| Cremona | 45.136 | 10.024 | – | F |
| Napoli | 40.855 | 14.260 | – | F |
| Rignano Garganico | 41.675 | 15.587 | – | F |
| San Marco in Lamis | 41.712 | 15.636 | – | F |
| Sannicandro Garganico | 41.835 | 15.567 | – | F |
| Lago di Varano | 41.875 | 15.750 | – | EE |

well-confined sequences [CSI Working Group, 2005]. The highest magnitude (ML 5.4) was reached by the first of a series of more than 100 events which affected the San Giovanni Rotondo-Cagnano Varano area from September 30 to the end of December 1995.

## 4. A Methodological Approach with a Difference

Studying historical earthquakes is an intricated business always, as witnessed by a wealth of case-histories and methodological articles, set forth in the last decades by distinguished exponents of this discipline [Ambraseys and Finkel, 1991, 1993; Stucchi *et al*., 1991; Guidoboni and Stucchi, 1993; Vogt, 1991, 1993; Musson, 1998; Guidoboni, 2000; Ambraseys, 2001]. Not least among the difficulties besetting the student of early modern earthquakes, is how to choose the potentially most rewarding items among the huge quantities of written sources produced in this period. Sizeable amounts of written records from the $16^{th}$–$18^{th}$ centuries have been preserved — often almost or even totally untouched by any previous research — in European repositories; choosing to favor one over another can have its consequences, as the case of the 1646 Gargano earthquake shows.

Past studies of the 1646 Gargano earthquake favoured a ''locally oriented approach'' in selecting sources. The earliest such studies were by Mario Baratta, one of the founding fathers of modern Italian seismology [Baratta, 1896, 1901]. Baratta relied on a handful of mostly non contemporary, mostly locally produced sources [Sarnelli, 1680; Giuliani, 1768], which provided him with written accounts on the earthquake's damaging effects in 10 sites of the Gargano peninsula. Guidoboni and Tinti [1989] and the studies included in the Catalogue of Strong Italian Earthquakes [Boschi *et al*., 1995, 1997, 2000] followed in Baratta's footsteps, with a research strategy chiefly aimed at the analysis of local church records and historiography and which steadily widened the exploited set of sources. The intensity table of the latest such study [Boschi *et al*., 2000] includes 17 intensity data points and (by showing the damage effects to be confined to the Gargano peninsula) basically confirms Baratta's view of the 1646 earthquake as a ''garganic'' event (Table 3).

This study adopts the opposite research strategy: its sources are strictly *contemporary* but not at all *local*. They are derived from some of the longest-lived early European newspapers (several of which are now being systematically studied for seismological purposes) and some of the most relevant bodies of diplomatic correspondence produced by the old sovereign states of northern Italy. In the early modern period, each regional capital of Italy was a storage point for miscellaneous information sent home by diplomats who gleaned news not only personally and through their own spies, but also from ''avvisi'' newsletters bought from professional journalists and routinely attached to homebound diplomatic reports. The data used in this study are derived from three main depositories: the Secretariate of State holdings at the Vatican Archives, and those of the Granduchy of Tuscany and the Duchy of Ferrara-Modena-Reggio, respectively, preserved at the State Archives of Florence and Modena. The Vatican Secretariate of State papers preserve the correspondence from the Nuncios (permanent representatives of the Pope to the foreign courts), that were expected to write at least once a week to the Cardinal Secretary of State, sending the latest news from their locations [Boyle, 1972]. The papers of the Medici Grandukes of Tuscany and the Este Dukes of Ferrara-Modena-Reggio also include files of letters by diplomatic representatives. The data hereby discussed were produced by the Neapolitan nunciature staff, and those of the Naples-based Tuscan consulate and Ferrarese embassy.

## 5. The 1646 Earthquake Sequence

### 5.1. The New Evidence

The earliest known mention of the 1646 earthquake is dated on June 2, 1646 [ASVat, 1646a] and concerns its being felt in Naples. As several contemporary Neapolitan sources attest (Table 4), shaking was felt on May 31 at 2:00 a.m., "*verso le sette hore di notte*" (around 7 hours of the night); it is reported to have lasted a very long time, as long as it would have taken to recite some of the longest Catholic prayers ("*due Miserere*", "*tre Credi*"), possibly about 20–30 s or more. Another source describes three separate shocks within 15 min [Nuova Relatione …, 1646].

On June 5, both the Papal Nuncio and the Florentine Consul in Naples were able to send home the first accounts from Apulia, on the severe damage and numerous victims which the earthquake had caused there [ASVat, 1646b; ASFi, 1646a]. On June 9, a fuller description was forthcoming: "*(ha) fatto cadere in più di 20 luochi molte Case, Campanili, e grosse Muraglie di fortezza con morte di mille Persone*" (in more than 20 localities it caused several churches, bell towers, and thick walls to collapse with 1,000 fatalities) [ASVat, 1646c]. On June 19, one apprehends that "*quasi tutte le case, che non erano cadute* […] *la maggior parte erano rimaste inhabitabili, et il danno fatto da terremoto si và ogni dì più scoprendo maggiore tanto nella mortalità delli habitanti come delle case*" (most of the houses that did not collapse […] are now uninhabitable, and day-by-day the earthquake damage shows itself to be more and more both on account of the number of fatalities and the affected buildings) [ASFi, 1646c]. The exact death toll remains vague, but it is likely to be around several hundred (Table 5).

### 5.2. Assessing Intensity from the New Evidence

Defining damage levels for the 1646 earthquake is a rather complex procedure. Most of the contemporary accounts (compiled not later than a month after the earthquake) give only a list of localities with a gross distinction between "damaged" and "severely damaged" ones, which far from easy to interpret in terms of intensity levels. More detailed descriptions can be found in an extremely rare journalistic pamphlet [Nuova Relatione…, 1646], printed in Trani, on the outskirts of the damaged area, a short time after the earthquake. For the purpose of damage assessment, one can also rely on a number of non contemporary sources, compiled from 30–120 years after the earthquake, possibly from oral tales or lost written reports. Sarnelli [1680] lists the number of fatalities and describes damage to buildings in 6 localities. Giuliani [1768] quotes an obituary listing 86 fatalities in Vieste (but Baratta [1896] reports 132 dead in Vieste, quoting the parish registers).

The terms and standard descriptions provided by these sources can easily be interpreted as belonging to three main categories (Table 6): severe widespread damage, with complete or partial collapse of most buildings (a), widespread damage with collapse of some buildings (b), and unspecified widespread damage (c). These definitions correspond to the MCS macroseismic scale levels X (a), VIII-IX (b), and VII-VIII (c) and to the EMS macroseismic scale levels X (a), VIII (b), and VII (c). The intensity levels have been formulated using this matrix and its comparison with the information retrieved for each locality, especially when quantitative descriptions are available (Table 7). Interestingly enough, the computed intensities agree with subsequent sources [Sarnelli, 1680; Giuliani, 1768; Baratta, 1896].

**TABLE 4** Chronology and contents of the 1646 earthquake news featured in the examined avvisi and gazettes

| Source | Date | sent from | sent to | Localities/areas quoted |
|---|---|---|---|---|
| ASVat, 1646a | June 2 | Napoli | Roma | Napoli. |
| ASFI, 1646a | June 5 | Napoli | Firenze | Napoli, Puglia (30 "places"), Vieste, Rignano, S. Marco, Sannicandro, Rodi, Peschici, Ischitella, Foggia, Fortore, Torremaggiore, Troia, Serracapriola, Manfredonia, Canosa, Monte S. Angelo. |
| ASMo, 1646a | June 5 | Napoli | Modena | Napoli, Puglia, Rignano, Sannicandro, Vieste, Peschici, Ischitella, Rodi. |
| ASVat, 1646b | June 5 | Napoli | Roma | Napoli, Puglia, Rignano, S. Marco, Sannicandro, Vieste, Ischitella, Rodi. |
| BAV, 1646a | June 9 | Roma | - | Puglia, 10 "places". |
| ASVat, 1646c | June 9 | Napoli | Roma | Napoli, Puglia, 20 "places", Monte S. Angelo, Vieste, Rodi, Rignano, Ischitella, Sannicandro. |
| ASFI, 1646b | June 12 | Napoli | Firenze | Barletta, Monte S. Angelo, Ischitella, S. Giovanni Rotondo,Vieste. |
| BAV, 1646c | June 16 | Roma | - | Provinces of Bari, Puglia and Capitanata; Monte S. Angelo, Vico, S. Giovanni Rotondo, Sannicandro, Rignano, Cagnano, Carpino, Ischitella, Rodi, Bari, Vieste, Manfredonia, Troia, Bovino, Ascoli, San Severo, Torremaggiore, Foggia, Policastro, S. Provenzo, Stimati. |
| BAV, 1646c | June 16 | Roma | - | Puglia, Capitanata. |
| ASVat, 1646d | June 16 | Roma | - | Napoli, Puglia, Capitanata, Vico, Monte S. Angelo, Nicastro, S. Gio. Rotondo, Rignano, Cagnano, Carpino, Ischitella, Rodi, Peschici, Vieste, Manfredonia, Troia, Bovino, San Severo, Torremaggiore, Bovino, Apricena, Tremiti. |
| Genova, 1646 | June 16 | Genova | - | Puglia, 8–10 "places". |
| ASMo, 1646b | June 19 | Napoli | Modena | Puglia. |
| ASFI, 1646c | June 19 | Napoli | Firenze | Puglia [same text of ASMo. 1646b]. |

**TABLE 5** Distribution of fatalities according to the main sources

| Locality | Historical Accounts | Number |
|---|---|---|
| Apulia and Terra di Lavoro (provinces) | *"molte migliaia di persone"* (several thousand people) [Settimanni, 18th c.]; *"con morte di mile Persone"* (a thousand people died) [ASVat, 1646c] *"considerabile mortalità di gente"* (considerable death toll) [ASVat, 1646b]; *"con mortalità di c.a. 800 persone"* (800 people died) [ASFi, 1646a]. | circa 1000 |
| Vieste | *"morte d'infinite persone"* (numberless dead) [Nuova relatione …, 1646]; *"restarono estinte 84 persone"* (84 people died) [Giuliani, 1768, from an inscription]; *"il numero totale delle vittime* […] *ascese a 132"* (the number of fatalities rose to 132) [Baratta, 1896, from parish registers]. | 132 |
| Ischitella | *"non restarono in piede, che venti case, colla morte di 86 persone"* (only 20 houses remained standing and 86 people died) [Giuliani, 1768]; *"opprimendo 96 persone, che vi restarono estinte"* (with the death of 96 people) [Sarnelli, 1680]; *"non vi è rimasto altro che trenta persone e tutte stroppiati"* (only 30 people survived, all injured) [Cardassi and Cardassi, 17th c.]. | 86/96 "many" |
| Vico Garganico | *"e si sono trovate morte da cento cinquanta persone"* (some 150 people were found dead) [Nuova relatione …, 1646]; *"quaranta uomini morirono sotto le pietre"* (40 people died under the rubble) [Sarnelli, 1680; Giuliani, 1768]. | 40/150 |
| Rodi Garganico | *"grandissima mortalità degli habitanti d'essa* […] *dicono sia il numero di trecento circa"* (extremely high death toll among its inhabitants, 300 people reported dead) [Nuova relatione …, 1646] *"sebbene soltanto ne morissero quattro"* (only 4 people died) [Sarnelli, 1680; Giuliani, 1768]. | 4/300 |
| Monte Sant'Angelo | *"scuotendosi il Monte à 7 hore di notte, & in Gargano diede il crollo à cento case, con restarne solamente cinque oppressi sotto le rovine"* (the mountain shook at 7 in the night, 100 buildings collapsed in Gargano, with only 5 people dead under the rubble) [Sarnelli, 1680]. | 5 |
| Manfredonia | *"cinque habitatori perirono"* (5 inhabitants died) [Sarnelli, 1680]. | 5 |
| Foggia | *"con la morte di due persone"* (2 people died) [Nuova relatione …, 1646]. | 2 |
| Canosa | *"Grandissima mortalità degli habitanti"* (a very high death toll among the residents) [Nuova relatione …, 1646]. | "many" |

**TABLE 6** Damage classification in journalistic sources and diplomatic correspondences

| a – severe damage and collapses affecting over half of the buildings |
|---|
| *"rovinati più della metà, ma quel poco che è restato in piedi, è in tal maniera aperto, e minacciante rovina … "* (over half the buildings destroyed, and what was left is severely damaged and about to collapse) [Nuova Relatione …, 1646]. |
| *"haver patito* […] *dicendosi essere caduta la maggior parte"* (most buildings have collapsed) [ASMo, 1646a]. |
| *"cascato tutto* […] *tutto rovinato a terra* […] *spiantato a terra"* (everything collapsed […] everything crashed to the ground […] or levelled to the ground) [Cardassi and Cardassi, 17th c.]. |
| *"havevano più patito* […] *si che di tutte queste terre non ci resterà in piede l'ottava parte"* (only the eighth part of the buildings must be still standing) [ASFi, 1646a]. |
| b – severe damage, with undefined collapse |
| *"cadendo con mortalità di molte persone alcuni luoghi d'importanza"* (some important places ruining down with a high death toll) [Bonito 1691, from manuscript reports by Torello]. |
| "rovinati, & atterrati" (destroyed and levelled to the ground) [Nuova Relatione …, 1646]. |
| c – unspecified severe damage |
| *"particolarm.te rovinati"* (particularly damaged) [BAV, 1646b]. |
| *"luoghi che hanno patito più di tutti"* (most affected localities) [ASVat, 1646b]. |
| *"havevano non poco patito le Città di … con li luoghi"* (suffered not a little damage) [BAV, 1646b]. |
| *"tutti rovinati"* (general destruction) [Cardassi and Cardassi, 17th c.]. |
| *"terre, e luoghi che avevano patito …"* (localities and places that suffered) [ASVat, 1646d]. |

- Ischitella. Listed by contemporary accounts among the localities "*rovinate e atterrate*" (damaged and leveled to the ground) with no further detail. According to Cardassi and Cardassi [17th century] "*non vi è rimasto altro che trenta persone e tutte stroppiati*" (only 30 people survived, all of them injured). Sarnelli [1680] reports that "*In Ischitella non restarono in più che ventisei case; le altre caddero tutte opprimendo novantasei persone, che vi restarono estinte*" (no more than 26 buildings remained standing, all the others collapsed killing 96 people).
- Vico del Gargano. Contemporary accounts agree in reporting very severe damage and more than 150 victims. Nuova Relatione… [1646] reports the collapse of the Capuchin convent, a detail confirmed by local Capuchins annals [Girolamo da Sorbo and Clemente da Napoli, 17th century; Bernardi, 17th century]. On the other hand, Sarnelli [1680] reports around 100 collapsed buildings and only 40 victims.
- Rodi Garganico. The most severely damaged locality according to all contemporary reports. Nuova Relatione [1646] reports it to be "*affatto spianata, con grandissima mortalità degli habitanti d'essa, de' quali non si può saper'il numero certo, per esser luogo assai popolato; ma alcuni di quelli, che sono restati, dicono sia il*

**TABLE 7** Intensities observed for the 1646 May 31 earthquake. References: (1) ASFi [1646a]; (2) ASFi [1646b]; (3) ASMo [1646a]; (4) ASNa [1646]; (5) ASNa [1647]; (6) ASVat [1646a]; (7) ASVat [1646b]; (8) ASVat [1646c]; (9) ASVat [1646d]; (10) BAV [1646c]; (11) Baratta [1896]; (12) Bernardi [17th c.]; (13) Bonito [1691]; (14) Cardassi and Cardassi [17th c.]; (15) Cavallini [2003]; (16) D'Alatri [1984]; (17) Girolamo da Sorbo and Clemente da Napoli [17th c.]; (18) Giuliani [1768]; (19) Latiano [1906]; (20) Nuova Relatione ... [1646]; (21) Paoloni [1913]; (22) Sarnelli [1680]; (23) Settimanni [18th c.]. (SB = Solitary Building; SS = Small Seattlement, HD = Heavy Damage)

| Locality | Coordinates | Int. MCS | Int. EMS | Ref. |
|---|---|---|---|---|
| Canosa di Puglia | 41.223 16.066 | 10 | 10 | 1, 4, 20. |
| Ischitella | 41.904 15.898 | 10 | 10 | 1, 2, 3, 7, 9, 10, 14, 18, 20, 22. |
| Peschici | 41.947 16.014 | 10 | 10 | 1, 3, 9, 13, 14, 17, 20. |
| Rodi Garganico | 41.929 15.884 | 10 | 10 | 1, 3, 7, 9, 10, 13, 14, 17, 18, 20, 22. |
| Vieste | 41.882 16.179 | 10 | 10 | 1, 3, 5, 7, 9, 10, 11, 13, 14, 17, 18, 19, 20. |
| Monte Sant'Angelo | 41.706 15.959 | 9/10 | 9 | 1, 2, 10, 14, 17, 20. |
| Rignano Garganico | 41.675 15.587 | 9/10 | 9 | 1, 7, 9, 10, 14, 17, 20. |
| San Giovanni Rotondo | 41.706 15.728 | 9/10 | 9 | 2, 9, 10, 13, 14, 17, 20. |
| San Marco in Lamis | 41.712 15.636 | 9/10 | 9 | 1, 7, 14, 17. |
| Sannicandro Garganico | 41.835 15.567 | 9/10 | 9 | 1, 3, 7, 9, 10, 17, 20. |
| Vico del Gargano | 41.895 15.958 | 9/10 | 9 | 10, 12, 14, 16, 17, 18, 19, 20, 22. |
| Manfredonia | 41.623 15.908 | 9 | 8/9 | 1, 9, 10, 20, 22. |
| Carpino | 41.843 15.857 | 8/9 | 8 | 9, 10, 14, 17, 20, 22. |
| Serracapriola | 41.806 15.159 | 8/9 | 8 | 1 |
| Torre di Fortore [SS] | 41.917 15.300 | 8/9 | 8 | 1 |
| Torremaggiore | 41.689 15.292 | 8/9 | 8 | 1, 9, 10. |
| Troia | 41.361 15.309 | 8/9 | 8 | 1, 9, 10. |
| Aspriano | 0.000 0.000 | 8/9 | 8 | 20. |
| Stimati | 0.000 0.000 | 8/9 | 8 | 10. |
| Abbazia di S. Maria di Pulsano [SS] | 41.677 15.909 | HD | HD | 15 |
| Torre di Giolice [SB] | 0.000 0.000 | HD | HD | 14. |
| Cagnano Varano | 41.826 15.775 | 8 | 7/8 | 9, 10, 13, 14, 17, 20, 22. |
| Apricena | 41.784 15.444 | 7/8 | 7 | 9, 17. |
| Ascoli Satriano | 41.205 15.561 | 7/8 | 7 | 10. |
| Bovino | 41.251 15.342 | 7/8 | 7 | 9, 10 |
| Foggia | 41.460 15.553 | 7/8 | 7 | 1, 10, 20. |
| San Severo | 41.685 15.381 | 7/8 | 7 | 9, 10. |
| Tremiti | 42.156 15.520 | 7/8 | 7 | 9 |
| Policastro | 0.000 0.000 | 7/8 | 7 | 9, 10, 20. |
| S. Provenco | 0.000 0.000 | 7/8 | 7 | 10. |

(*Continued*)

**TABLE 7** (*Continued*)

| Locality | Coordinates | Int. MCS | Int. EMS | Ref. |
|---|---|---|---|---|
| San Menaio Garganico [Santo Minale] | 41.934 15.951 | 7/8 | 7 | 14. |
| Bari | 41.106 16.846 | 5 | 5 | 10, 14. |
| Napoli | 40.855 14.260 | 5 | 5 | 6, 8, 17, 23. |
| Montecassino | 41.490 13.814 | 4 | 4 | 21 |
| San Germano | 41.488 13.830 | 4 | 4 | 21 |

*numero di trecento circa* [...] *ma Vico, e Rodi bisogna ergerli di nuovo dalli fondamenti*'' (completely destroyed, with an extremely high death toll among the residents, 300 dead according to the survivors [...] Vico and Rodi will have to be rebuilt from the ground up).

- Vieste. Listed among the very severely damaged localities, but no accurate accounts are available. Nuova Relatione [1646] reports it to be ''r*ovinata affatto* [...] *con la morte d'infinite persone, delle quali non si sà il numero, per esser rimasti sotto le pietre*'' (utterly ruined [...] with numberless casualties, impossible to count as the bodies remain under the rubble). According to a contemporary chronicler [Gabriele da Cerignola, 17$^{th}$ century, in Latiano, 1906], most of Vieste fell down in the quake, the castle and the ''Scoglio'' tower included, but the Capuchin convent (built outside the town, as prescribed in the Order rules) remained standing and the survivors found shelter there.
- Canosa di Puglia. According to Nuova Relatione [1646] ''*cadero* [...] *da cento cinquanta Case, & il castello fù rovinato, e spiantato affatto, che non si scorge altro*'' (some 150 houses collapsed, the castle was ruined and utterly uprooted, leaving no visible vestige). The Florentine Consul in Naples describes Canosa as ''*tutta spianata*'' (completely leveled to the ground) [ASFi, 1646a].
- Peschici. One of the most grievously damaged localities according to several reports. According to contemporary memoirialists Girolamo da Sorbo and Clemente da Napoli [17$^{th}$ century], ''*Peschise è cascato quasi tutto*'' (almost all fallen down).

Very severe damage did not stop at the Gargano peninsula but extended inland, westward to the Daunian Appennines, southward to the flatlands of Capitanata and eastward to the Tremiti Islands [ASVat, 1646d]. The contemporary accounts agree in listing Gargano sites (Manfredonia, Monte Sant'Angelo, Rignano Garganico, San Giovanni Rotondo, San Marco in Lamis, Sannicandro Garganico) as ''*rovinate più della meta*'' (more than half ruined), but they also add that severe damage occurred in the inland town of Torremaggiore as well (nearby Apricena and San Severo were less grievously affected). In the province of Capitanata, Troia and Serracapriola suffered worse damage than Bovino and Ascoli (now Ascoli Satriano); in Foggia, the provincial capital, ''*rovinarono sei Case, ma solamente con la morte di due persone*'' (six houses collapsed, but only two people died) and the convent of the Capuchins was badly shaken. As previously mentioned, the main shock was clearly felt in Naples (causing widespread panic) and in the Montecassino area, as reported by Paoloni [1913] quoting the contemporary diaries of the Benedictine abbey.

Most of the quoted sources being handwritten and based on previous accounts (both verbal and written) the place-names mentioned in them are often distorted, owing either to the inaccuracy or the ignorance of some copyists. In most cases, it is easy to recognize which locality is which; however, a few damaged sites (Aspriano, San Provenzo, Stimati, Torre di Giolice) are still to be identified. Some doubt also affect a report of damage in "Policastro," given without more details by Nuova Relatione [1646]. There is a locality called Policastro in Calabria but it is unclear whether the author had it in mind or not; moreover, given its considerable distance from the most affected area, it remains to be seen whether this report should be connected to the 1646 Apulian earthquake or to some contemporary, and otherwise unknown, Calabrian earthquake.

On the whole, the new dataset for the 1646 earthquake includes 35 intensity datapoints, from which an epicentral intensity *Io* X degree, both on the MCS and the EMS macroseismic scales can be derived (Table 7). The new scenario emerging from this study shows a very strong earthquake whose effects involved an area much larger than it seemed before this study (Fig. 3)

### *5.3. Seismic Sequence and Aftershocks*

After the main event of January 31, a number of shocks were felt, according to the contemporary reports. A letter written in Naples on June 12 [ASFi, 1646b] quotes a three-day-old report from Apulia, with news of a shock felt in Barletta with no reported damage. A subsequent letter, dated June 19 [ASFi, 1646c] mentions more shocks "*di quando in quando s'andavano sentendo*" (being felt every now and then), on account of which reason "*molte persone dormivano in Campagna sotto baracche*" (many people slept within shacks in the open country).

### *5.4. Environmental Effects*

Sarnelli [1680] reports that "*gli Orti di Carpino si trovarono pieni delle conchiglie del lago*" (the Carpino orchards were found filled with shells from the lake), probably on

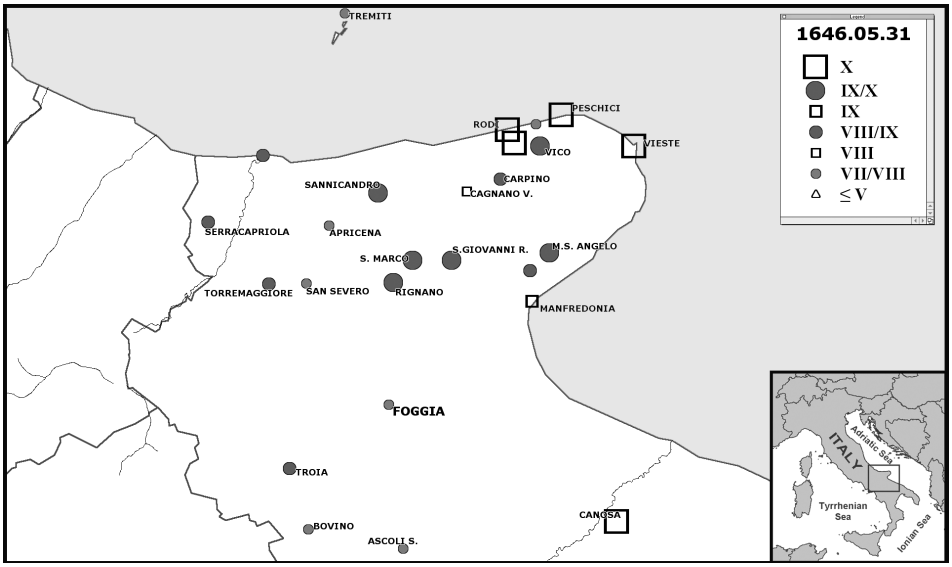


**FIGURE 3** The 1646 Gargano earthquake intensity map after the present study.

account of a shockwave that caused the nearby Lake Varano to overflow. According to Cardassi and Cardassi [17th century], sailors reported that a sudden sea-roughness was felt even by the larger boats. These accounts are not enough, however, to affirm that a tsunami occurred; for this reason the 1646 earthquake was not included in the most recent Tinti and Maramai [1996] catalog of Italian tsunamis.

A letter written in Naples on June 12 [ASFi, 1646b] mentions the occurrence of wide cracks in the ground, at Monte Sant'Angelo, Ischitella, and San Giovanni Rotondo. Girolamo da Sorbo and Clemente da Napoli [17th century] mention the spilling of water out of cisterns in Rodi Garganico.

## 6. Minor Events Following the 1646 Earthquake

The ending of the 1646 earthquake did not bring quiet to the Gargano peninsula. Over the next 40 years, there is evidence of at least 3 other locally damaging events, information on which is hereby summarized.

### *6.1. 1647: A Forgotten Earthquake*

At the end of May 1647, the Bologna gazette [Bologna, 1647] reported on an earthquake that — according to some recent letters from Apulia — had lately struck the Gargano peninsula. On May 5 (at 12:30 a.m. GMT), two shocks (allegedly stronger than the previous year's ones) had severely damaged Vieste and Monte Sant'Angelo and, to a lesser degree, some inland localities in the general direction of the Appennines (Serracapriola, Lucera and San Severo). "*More details will be forthcoming with the next reports*" promised the Bologna gazette. In fact, no more details were to come; a rebellion against the Spanish government (known as " the revolt of Masaniello") was about to break out in Naples causing a wave of minor riots, looting and bloodshed which would engulf most of southern Italy, Apulia included. Over the next months, all newspapers would follow the developments of the rebellion, to the exclusion of everything else. The Apulian earthquake slipped into oblivion and there remained until it was recently brought to light by a systematic perusal of the Bologna gazette. Even if its reported effects are likely to have been magnified by their almost exact superimposition on those caused by the 1646 earthquake, a preliminary evaluation of the 1647 earthquake shows it to have been a sizeable event (Table 8, Fig. 4)

### *6.2. 1656–1657: A Barely Remembered Earthquake*

A decade passed and the Gargano peninsula shook again. The authoritative earthquake compilation by Baratta [1901] collected evidence of a damaging shock in San Severo, on

**TABLE 8** Intensities observed for May 5, 1647 earthquake

| Locality | Coordinates | Int. MCS | Int. EMS | Ref. |
|---|---|---|---|---|
| Vieste | 41.882 16.179 | 7/8 | 7 | Bologna [1647] |
| Monte Sant'Angelo | 41.706 15.959 | 7/8 | 7 | Bologna [1647] |
| Serracapriola | 41.806 15.159 | 6/7 | 6 | Bologna [1647] |
| Lucera | 41.508 15.335 | 6/7 | 6 | Bologna [1647] |
| San Severo | 41.685 15.381 | 6/7 | 6 | Bologna [1647] |

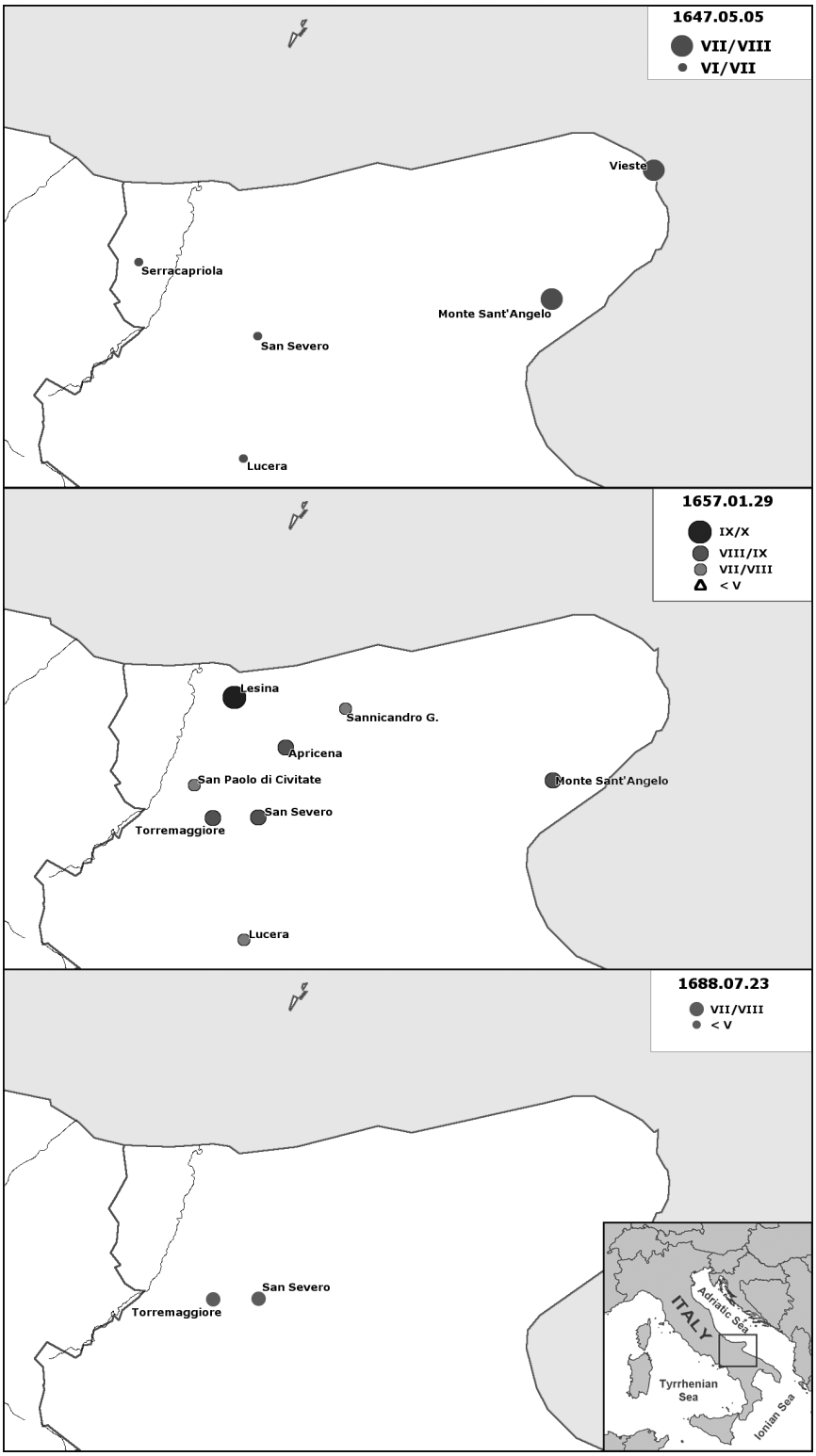


**FIGURE 4** Localities affected by the 1647, 1657 and 1688 Gargano earthquakes.

October 17, 1656 (source: Sarnelli, 1680), and one in Lesina, in January 1657 (source: Corradi, 1865–1894). Both testimonies, Baratta suggests, could be related to a single earthquake, whose likeliest date of occurrence he thought to be October 17, 1656. Only partially heeding his advice, the Postpischl [1985] and CPTI Working Group [2004] catalogs list a VII MCS earthquake in the vicinity of Lesina, on January 1657.

A careful study of Baratta's sources brings to light an intricated situation. Sarnelli [1680] cites the event of October 17, 1656 in the context of a "miracle story"; during that year's summer plague outbreak — he says — the Archbishop of Siponto had a vision of St Michael Archangel, which inspired him to predict a forthcoming earthquake; on October 17, that prophecy came true. A pious legend or there could be a grain of truth in it? What's certain is that Sarnelli [1680] cut down a longer tale related by his source (Cavalieri, 17th century, a history of the famed Garganic shrine of St Michael in Monte Sant'Angelo). Actually, this source mentions not one but two earthquakes: a minor shock on October 17, 1656 (presumably felt in Monte Sant'Angelo, no effects described), and a major one *"at night on the 1st of February* [1657]"; the latter was "*felt as far as Naples* [and] *struck, shook, disrupted and razed to the ground"* several Garganic sites (Lesina, Lucera, San Nicandro, San Paolo, San Severo).

Let's now consider Corradi [1865–1894], the other source quoted by Baratta [1901]. He cites ASFi [1657a], a diplomatic report written on January 30, 1657 by a Florentine resident in Naples and describing *"a mighty quake that frightened all the city"* on the night of January 29–30. This piece of news is — by the way — independently confirmed by another diplomatic report written on the same day [ASMo, 1657].

Had Corradi [1865–1894] delved farther into the Florentine records, he would have found that a month after the previous letter, the Florentine resident had more to say on the same topic: *"That earthquake I wrote about, has turned out to have caused huge damage in Apulia, particularly in San Severo, Torremaggiore, Casal Maggiore [now Apricena], Monte Sant'Angelo and above all in Lesina"* [ASFi, 1657b]. This description fits well with the one by Cavalieri [17th century], with only a slight difference in the date (January 29–30 according to ASFi [1657a]; February 1 according to Cavalieri, 17th century). It seems reasonable to identify the mainshock of the Apulian event with the one felt as far as Naples, and therefore to accept the date given by ASFi [1657a]; the one given by Cavalieri [17th century] could be either a mistake or related to one of the aftershocks mentioned by ASFi [1657b].

For the time being, no more evidence is forthcoming on the 1657 earthquake, apart from a brief reference to the damage it wrought in San Severo by a local contemporary source [Fraccacreta, 17th century]; however, judging from the currently available original sources, this earthquake was undoubtedly underestimated by previous catalogues (Table 9, Fig. 4). The main event occurred probably on January 29, 1657 (at 1:40 a.m. GMT); it could have been preceded by a minor shock (October 17, 1656) and was certainly followed by a few aftershocks (early February 1657); the NW side of the Gargano peninsula seems to have been the most heavily affected area.

### *6.3. 1688: An Overlooked Earthquake*

In 1688 the Gargano peninsula was once more stricken by a "*gran terremoto*" (big earthquake). This is not a "forgotten" earthquake but rather an overlooked one. Baratta [1901] knew it, and the Postpischl [1985] catalog listed it with *Io* = VI MCS. The CPTI04 catalog [CPTI Working Group, 2004] does not list it anymore, probably because of the declustering procedures adopted for its compilation. The main provider of data on this earthquake is a contemporary Neapolitan diary [Conforto, 17th century], according to which it was felt in Apulia and Calabria on July 23, 1688 (at 8.00 a.m local time), causing

**TABLE 9** Intensities observed for January 29, 1657 earthquake. References: (1) ASFi [1657a]; (2) ASFi [1657b]; (3) ASMo [1657]; (4) Cavalieri [17th c.]; (5) Fraccacreta [17th c.]

| Locality | Coordinates | Int. MCS | Int. EMS | Ref. |
|---|---|---|---|---|
| Lesina | 41.864 15.353 | 9/10 | 9 | 2, 4. |
| San Severo | 41.685 15.381 | 8/9 | 8 | 2, 4, 5. |
| Torremaggiore | 41.689 15.292 | 8/9 | 8 | 2. |
| Apricena [Casal Maggiore] | 41.784 15.444 | 8/9 | 8 | 2. |
| Monte Sant'Angelo | 41.706 15.959 | 8/9 | 8 | 2. |
| Sannicandro Garganico | 41.835 15.567 | 7/8 | 7 | 4. |
| San Paolo di Civitate | 41.739 15.261 | 7/8 | 7 | 4. |
| Lucera | 41.508 15.335 | 7/8 | 7 | 4. |
| Napoli | 40.855 14.260 | 4/5 | 4/5 | 1, 2, 3, 4. |

**TABLE 10** Intensities observed for July 23, 1688 earthquake

| Locality | Coordinates | Int. MCS | Int. EMS | Ref. |
|---|---|---|---|---|
| San Severo | 41.685 15.381 | 7/8 | 7 | Conforto [17th c.] |
| Torremaggiore | 41.689 15.292 | 7/8 | 7 | Conforto [17th c.] |
| Napoli | 40.855 14.260 | 3? | 3 | ASVat [1688] |

minor damage in Sansevero, Torremaggiore and nearby towns (Table 10, Fig. 4). Bonito [1691] affirms that these news were brought to Naples by *"several letters"*, presumably despatched from the affected areas. So far, no additional evidence for this earthquake was found, either in early newspapers or in local histories. A recently felt quake is mentioned in an August 31 letter by the Papal Nuncio in Naples [ASVat, 1688], but it is unclear whether this is a reference to the Apulian event or to an aftershock of the strong Neapolitan Apennines earthquake of June 5 1688 (Mw = 6.7 [CPTI Working Group, 2004]). The minor Apulian earthquake could have been "blanked out" by the larger one (on this subject see Camassi and Castelli, 2005); there is no reason to doubt of its occurrence, although no very accurate assessment of its size can be made from the available evidence.

## 7. Discussion and Seismotectonic Implications: Evidence of an Earthquake Cluster ?

The epicentral parameters of the discussed 17th century earthquakes (Table 11 and Fig. 5) have been assessed with the standard Boxer code procedure, based on the

**TABLE 11** New epicentral parameters of the four studied earthquakes

| Date | Time | Epicentral Area | Max. Int. | Epic. Int. | Om | Lat | Lon | Mw |
|---|---|---|---|---|---|---|---|---|
| 1646 05 31 | 02 00 | Gargano | 10 | 10 | 35 | 41.905 | 15.993 | 6.85 |
| 1647 05 05 | 12 30 | Gargano | 7/8 | 7/8 | 5 | 41.732 | 15.558 | 5.69 |
| 1657 01 29 | 01 40 | Lesina | 9/10 | 8/9 | 9 | 41.726 | 15.393 | 6.37 |
| 1688 07 23 | 03 00 | San Severo | 7/8 | 7/8 | 3 | 41.687 | 15.337 | 5.35 |

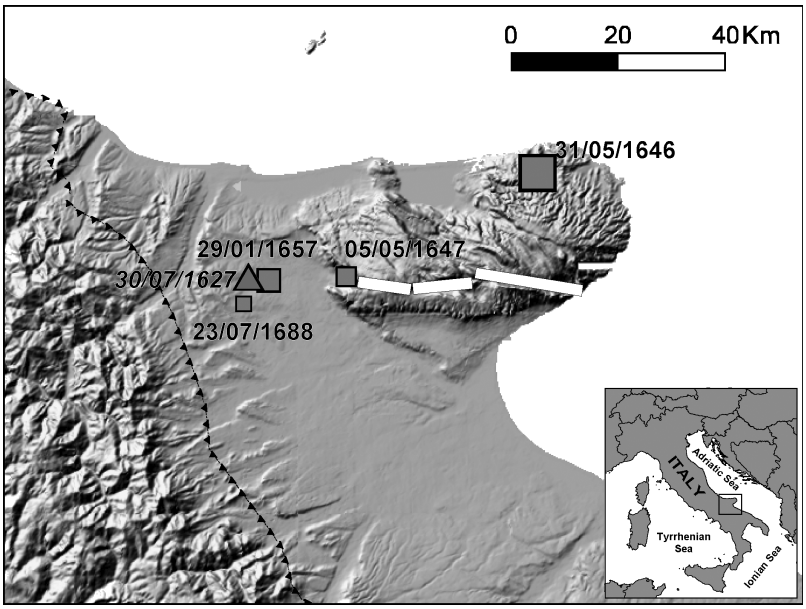


**FIGURE 5** Macroseismic epicentres of the studied earthquakes.

distribution of macroseismic observations [Gasperini *et al.*, 1999], with the following results.

**1646:** The dataset presented in Table 7 leads to assessing a macroseismic moment magnitude Mw of 6.9. This value is much higher than the macroseismic magnitude Me = 6.2 estimated (with the same standard procedure) by Boschi *et al.* [2000]. Accepting it would put the 1646 earthquake on the same level of the better-defined 1627 earthquake (Mw = 6.7 [CPTI Working Group, 2004]), currently viewed as the strongest earthquake on record in the Gargano-Capitanata area and one of the most relevant of Southern Italy as well. Such a decision ought not be taken lightly and without first considering whether the data could be interpreted otherwise or the proposed assessment be questioned. For instance, however reliable and consistent the available contemporary descriptions of the severe damage wrought by the 1646 earthquake, it could be argued that it could have been at least partly due to the heightened vulnerability of buildings that had been affected by a very strong earthquake only 19 years before, in 1627. In fact, however, the latest available study of the 1627 earthquake [Boschi *et al.*, 2000] points out that — also thanks to a favorable economic conjuncture — the restoration process was quickly and efficiently carried out and that most privately owned buildings and many of the Church-owned ones were set to right within 10 years.

The criteria of the Boxer code procedure could also have contributed to enhancing the assessed magnitude value by attributing an excessive weight to the macroseismic data point with the highest intensity and farther-removed from the others (Canosa di Puglia).

**1647:** From the dataset presented in Table 8, Mw = 5.9 and *Io* = VII-VIII MCS can be assessed for this hitherto unknown earthquake.

**1657:** CPTI Working Group [2004] assesses M = 4.8 and *Io* = VII MCS for this earthquake (Table 2), generically dated to January 1657. The dataset presented in Table 9 allows to pinpoint its date to January 29, 1657, at 1:40 a.m., with Mw = 6.4, *Imax* = IX-X MCS and *Io* = VIII-IX MCS, consistent with the destructive level of its effects.

**1688:** Postpischl [1985] assesses M = 4.1, *Io* = VI MCS for this earthquake (Table 2); this revision proposes Mw = 5.4 and *Io* = VII-VIII MCS.

It is important to underline that the Boxer procedure [Gasperini *et al*., 1999] adopted for determining the epicentral parameters is strongly dependent on the assigned intensities; of course the proposed magnitudes have an associated error, in this work evaluated in ±0.5 as mean value; this high error is a sort of measure of the stability of the determination.

The four earthquakes reconstructed in this study define a 42-year-long period of high seismic activity that affected the Gargano area in the 17$^{th}$ century and which had been almost completely overlooked by the Italian seismological tradition. Up to until now, instrumental observation had showed that Gargano earthquakes tend to cluster themselves in time and space, but no historical evidence of this tendency was available. The results of this study seem to point out to the existence of at least one such case in the 17$^{th}$ century.

The distribution of the macroseismic epicenters (Fig. 5) shows—with the reduced level of reliability inherent to the adopted methodology—an East to West spatial migration during a short time, which would appear to be in contrast with the distribution of the damage reports here presented. Furthermore, the characteristics of the area make it unlikely that propagation events might follow this specific distribution.

It is therefore plausible that the distribution of the epicentres follows portions of the Mattinata fault system, which have been activated in a sequential manner, probably because of the huge amount of energy released and the general disturbance caused by the 1627 earthquake.

Of course, it is not the aim of this study to define the clustering property of the seismicity in the studied area, nor to propose any quantitative analysis of fault-interaction processes that can justify the studied 17$^{th}$ century seismic sequence. However, the available evidence seems undoubtedly to converge in supporting the hypothesis of a trigger of different segments of the Mattinata fault.

This kind of observation is very important when the seismic hazard is assessed adopting a time-dependent model, such as the one proposed by Faenza *et al*. [2003]; this approach is based on the clustering of earthquakes with M > 5.5 and it can evaluate the increase of the probability of occurrence of an earthquake in a short time period after a big event. Therefore, the results of this study point out that, when modeling possible seismic scenarios for the Gargano area, it should be advisable to analyse short term return periods, in which the interaction amongst the adjacent fault segments could generate new similar sequences in the wake of forthcoming severe earthquakes.

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